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GISualization: visualized integration of multiple types of data for knowledge co-production

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ABSTRACT

Urban planning deals with multiple layers of information stemming from concurrent activities and stakeholders intervening in urban development. For a better management of complexity more comprehensiveness and data integration are needed. This study develops an adaptive and iterative mixed-method approach for knowledge production in urban transformation processes. Specific research questions relate to data integration from different sources and facilitation of co-production of knowledge beyond triangulation. A new multi-layer framework, GISualization, has been developed in the context of a research project exploring compact city qualities. The framework is structured through five data layers, representing different methods for data collection and different grades of complexity, richness and interpretation: basic statistics; advanced statistics; exogenous quali-quantitative descriptions; exogenous qualitative descriptions; and endogenous qualitative descriptions. Thus, data stem from both quantitative and qualitative sources. Our study has proven that GISualization is a methodological framework that enables analysis and visualization of complex data in a rich format. The approach is closely related to analytical eclecticism and abductivity. It embodies a collaborative communication platform that provides a language to navigate between heterogeneous data, information and methods. The GISualization framework opens up for broader stakeholder involvement and community participation extending research into the domain of transdisciplinary knowledge production.

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GIS; visualization; beyond triangulation; mixed-method; group learning; GISualization

1. Introduction

Understanding the complexity of contemporary cities involves a multiplicity of components that interact in shaping urban reality. Urban planning is about integrating multiple layers of information and data resulting from concurrent and diverse driving forces and stakeholder activities intervening in urban development. This means that cities are forged through the "transformation of various informational levels into spatial constructions" which, among other things, involves the "organization of information into forms of visual representation" (Paklone & Strautmanis, 2009, p. 35). As stated by Kuhn (2012, p. 2268) "spatial information" should be "seen as an enabler for solving societal problems across disciplinary boundaries". Communication between academics, society and stakeholders is key to paving the way for the achievement of the UN Sustainable Development Goals (United Nations, 2015).

The methodological challenges stemming from such multi- and transdisciplinary knowledge production need to be faced through enhancing the use of Information and Communication Technology (ICT), including Geographic Information Systems (GIS) (Sheppard, 2005) and softGIS (Kahila & Kyttä, 2009). Here, the value of GIS is twofold: on the one hand, as a platform for mixed-method co-production of knowledge and, on the other hand, as an instrument for delivering information and knowledge through visualization techniques.

The aim of this paper is to present a new concept—GISualization (pronounced: ˈʤizjʊəlaɪˈzeɪʃən)—involving an adaptive and iterative mixed-method approach for integrated knowledge production in studies of urban transformation processes, the example case being a comprehensive understanding of urban qualities in an ongoing research project on compact cities. By identifying integrative visualizations as a main focus of research and method development, the term GISualization is coined. This term captures an approach to synthesizing multiple layers of knowledge that is an extension of pure GIS-based visualization capabilities. In GISualization, GIS maintains a central role as the main visualization tool but it is integrated with other complementary visualization types. Additionally, even if procedures and methods used during the research embrace more than just visualization,

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visualization is used as the enabling platform for dialogue among researchers and dissemination of academic knowledge. The following research questions are explored: How can different kinds of data from different sources be integrated through GISualization? How can such an approach facilitate co-produced knowledge development beyond triangulation?

2. Literature review and theoretical framework

From an analysis of previous research and literature, five key issues stand out in relation to the use of GIS visualization for integration of data and knowledge co-production: (1) the question of representation of diverse types of data and their integration through GIS; (2) the introduction of a qualitative dimension of GIS, connected to its socio-political value; (3) the use of mixed-method approaches to combine qualitative and quantitative layers of information; (4) the need for a deeper level of knowledge trespassing simple triangulation of different data sources; and (5) the need of group learning and integration of non-GIS visualization.

First, the question of data integration and representation is intrinsic to the use of GIS as a technology, whose main purpose is to combine maps with databases. Still, the nature of GIS data themselves is complex. Geographic information may be interpreted through different "ontologies" (Couclelis, 2010) as you need to conceptualize and connect different data with different semantic values (existence, function, location, etc.). Therefore, it is key to address "semantic interoperability" between GIS layers and the existence of "multiple representations (…) of the same entity" (Couclelis, 2010, p. 1803), for example different ways of categorizing data. By doing so, it connects to GIScience, a term that includes more theoretical and conceptual "questions of spatial data structures, analysis, accuracy, meaning, cognition, visualization, and many more" (Wright, 2010, p. 1285).

Second, there is a social side of GIS connected to the introduction of qualitative aspects in GIS-based analysis. Born as a quantitative-oriented analytical tool, GIS has gradually incorporated also qualitative data and mixed perspectives. The importance of integrating qualitative research into GIS has been supported by feminist studies (Kwan, 2002a, 2002b; Pavlovskaya & St. Martin, 2007) and is nowadays academically acknowledged (Cope & Elwood, 2009; Kahila & Kyttä, 2009; Picone & Lo Piccolo, 2014). Pickles describes GIS as a "social actor" (Pickles, 2006, p. 763) and underlines the importance to include socio-political dimensions within GIS analysis. Still, recent literature criticizes conventional or "mainstream GIS" for "masking alternative versions of social reality" and "neglecting the socio-economic organization of people in geographical space from the perspective of minorities" (Fielding & Cisneros-Puebla, 2009, p. 352). Dunn (2007) connects the need to include socio-political dimensions to the emergence of Participatory GIS (Abbot et al., 1998). Miller (2007) goes beyond the typical "place-based" GIS approach introducing a "people-based" perspective, as human activities are not only depending on places and can be fragmented through space and time. For example, with ICT and the Internet, there is not always a "close connection between particular places and activities" (Miller, 2007, p. 508).

Third, taking into account the aforementioned complexity of human activity and relationships, a wider theoretically and methodologically mixed approach to visualization and GIS is key to grasping such complexity. From a theoretical perspective, the transversal character of current GIS studies displays theoretical/conceptual commonalities with "analytic eclecticism" (Sil & Katzenstein, 2010) which argues for a combination of theories to deal with complex phenomena. Such an eclecticism may be adopted from a theoretical, but also from a methodological perspective (Ahmed & Sil, 2012). For this reason, Knowles, Westerveld, and Strom (2015) advocate a broader "range of geographical methods for visualizing the spatiality of human experience" using an inductive approach, an argument shared also by other authors (e.g. Jung & Elwood, 2010; Knigge & Cope, 2006). This is in line with a general shift in the research literature, where mixed-method approaches have gradually emerged as a "research paradigm" on its own (Johnson, Onwuegbuzie & Turner, 2007). For mixed-method GIS, Matthews, Detwiler, and Burton (2005) use geo-ethnography, which combines GIS with ethnographic methods. Knigge and Cope (2006) and Jung and Elwood (2010) achieve an integration of qualitative and quantitative data through grounded theory. Kwan and Ding (2008) adopt a geo-narrative approach to mixed-method analysis by adding a qualitative software component to GIS. This interest in a combined use of GIS and qualitative software (CAQDAS) is shared by Fielding and Cisneros-Puebla (2009). Still, the limitations of such technological hybridity are academically acknowledged, where, for example Kwan and Ding state that their qualitative analysis is still "basic" and not "comprehensive" (2008, p. 459). Fielding and Cisneros-Puebla (2009, p. 352) observe that even if "published examples currently pursue a 'fuller picture' rather than triangulation-for-convergence approach (..) there are signs of triangulation-type reasoning" (Fielding & Cisneros-Puebla, 2009, p. 352).

This leads us to the fourth element of discussion found in the literature, which is the need for extending the mixed-method approach beyond simple triangulations of data. Triangulation is normally associated with data validation although some authors (Nightingale, 2003; Yeasmin & Rahman, 2012) have proposed to rethink triangulation as a process of combining methods or techniques rather than just being about verifying/contradicting data results from different sources. Nevertheless, as triangulation still mostly tends to be used for "cross-checking" (Yeasmin & Rahman, 2012, p. 157) data, methods or techniques, it "is not an end in itself" (Yeasmin & Rahman, 2012, p. 160). There are other reasons for mixing data than just triangulation, such as to "develop or inform other methods", where "one method can be nested within another method" and "methods can serve a larger, transformative purpose" (Creswell, 2003, p. 16). Such needs may lead to "sequential", "concurrent" or "transformative procedures" (Creswell, 2003, p. 16). Developing methods that bring mixed-method GIS beyond triangulation thus constitutes a knowledge gap to be filled. Here, informatics-oriented approaches (Renz, 2002; Schuurman & Leszczynski, 2006; Yao & Thill, 2006) may provide a partial response to GIS data integration but more comprehensive solutions are still needed. Through a more conceptually and theoretically rooted approach, Brown, Strickland-Munro, Kobryn, and Moore (2017) have proposed an evaluation of non-spatial and spatial agreements/disagreements of mapped qualitative and quantitative data, with a participatory GIS focus. Moving beyond GIS as a purely technical tool, Babelon, Ståhle, and Balfors (2017) propose an ontological and epistemological interpretation of web-based participatory GIS as cyborgs to highlight their mixed socio-technical character. Hence, a paradigm shift seems necessary, similar to the theoretical shift from "Geoinformatics" to "Choroinformatics" (Koutsopulos, 2011) leading to a more holistic and integrative approach that gives precedence to interdisciplinarity before multidisciplinarity. Accordingly, Kuhn (2012) highlights the contribution of GIS to research by bringing together scientists from many disciplines. When diverse quantitative and qualitative "methods and their associated practices are reflexively blended" the outcome should become "more than the sum of its parts" (Cope & Elwood, 2009, p. 171).

The social and participatory side of GIS and the needs for interdisciplinarity and reflexivity for moving beyond simple triangulation brings forward the fifth issue of GIS visualization. Previous research has explored the connection between visualization and collaborative learning (Hayashi, Ogawa, & Nakano, 2013). Co-production of knowledge is typically associated with involvement of non-scientific actors, such as policy makers (Kemp & Rotmans, 2009) or citizens (Campbell, 2012; Watson, 2014), but might also take the form of a collaborative effort among researchers, as stated by Frantzeskaki and Kabisch (2016) who underline the role of scientists in knowledge co-production. Following Burkhard (2005), co-production of knowledge is achievable through visualization, which supports "individuals or a group of individuals to transfer knowledge and to create new knowledge in collaborative settings" (Burkhard, 2005, p. 136). Here, complementary visualization methods "can be used to improve the transfer of knowledge in organizations" (Burkhard, 2005, p. 2). All in all, co-production of knowledge through group learning is necessary for moving beyond simple triangulation, and for such group learning complementary non-GIS visualization methods need to be incorporated.

3. Methodology—development of the GISualization framework

The GISualization approach has been developed within an ongoing research project: "Compact Cities? – Exploring qualities, drivers and strategies for promoting mixed-use urban development", a project that seeks to contribute to a more operational understanding of which qualities a compact city needs to include and how they can be promoted and realized. The GISualization framework was developed as part of the case-based, incremental and iterative research process applied in this project. This process involved parallel and concurrent activities of a) collecting and analysing data on compact city qualities and b) developing the GISualization methodological approach in support of integrative analysis and synthesis of the collected data. Data were gathered at different levels of aggregation, for a city as a whole as well as for a number of case areas within in the city, and also from multiple stakeholders at different levels. The research started with the ambition to integrate multi-stakeholder and multi-spatial perspectives through a mixed-method approach. Following Johnson et al. (2007), GISualization may be described as methodologically mixed, but "qualitative dominant" (Johnson et al., 2007, p. 124) in its reasoning, as qualitative sources (e.g. interviews and literature) are predominantly used to determine the core elements of the analysis. Although previous research on the compact city has adopted GIS visualization techniques (e.g. Abdullahi, Pradhan, Mansor, & Shariff, 2015; Min, Suxia, & Liang, 2012) these appear too focused on particular aspects or GIS representation techniques. In the course of the research project a multi-layer framework evolved to manage the resulting complexity of data collection and analysis. The concept of GISualization thus emerged based on the need for more comprehensiveness and integration. The GISualization approach works like a toolbox composed of a broad range of methods and tools. Within an established multi-layer structure (section 4.1) and iterative process for academically co-produced knowledge, researchers can draw on the different methods and tools and select ad hoc the most suitable ones for a specific research objective. Therefore, the GISualization framework should be applied as an adaptive and flexible framework rather than a rigid and generic approach.

To develop the GISualization framework, periods with field studies and intense data collection were alternated with half-day and one day meetings with all involved researchers, functioning as group learning sessions (Figure 1) in which the GISualization framework was critically discussed and developed collectively. The research team consisted of people with different backgrounds, such as architects, planners and

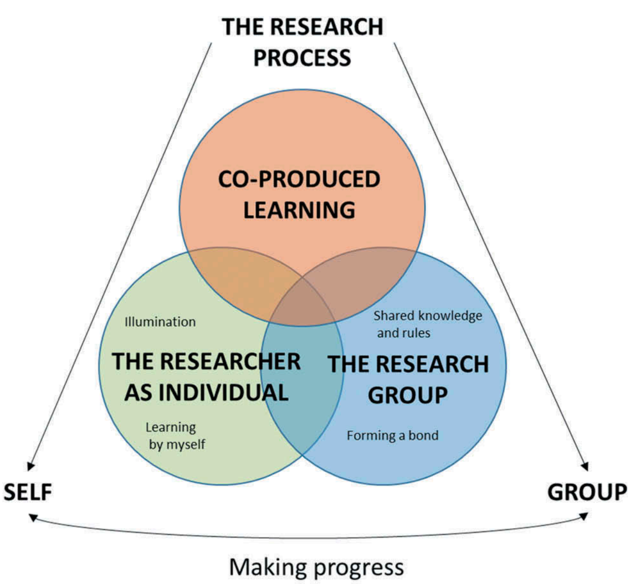


Figure 1. Group learning process among involved researchers. Inspired from: Wilson, McCormack, and Ives (2008, p. 26).

geographers. So far, the GISualization framework has only been applied by a small group of academic researchers. Trials involving a more mixed and larger group of knowledge-producing stakeholders are a necessary next step to fully engage with the critical need of more democratic and inclusive knowledge production (Schuurman, 2006).

In order to explore and structure the collected data, the research team developed an analytical framework (Table 1). In principle, the framework describes main categories of compact city qualities, labelled as people, built structures, nature, socio-culture, environment, economy, health, quality of life, justice and adaptability, and subdivided into states and impacts linked to compact city development. This analytical framework is further differentiated by drawing on the five main attributes of compact cities: intensity, diversity, proximity, connectivity and concentration (see also Kain et al., 2016). Thus, the GISualization concept has been developed and tested as a methodology to support a goal-oriented analysis and synthesis (Cohen, 2017), that is the understanding of compact city qualities. Even if the GISualization concept has been developed and implemented by experts (researchers) in a research environment so far, the long-term ambition is to establish a framework that is useful for different stakeholders from academia and society.

In the following sections, the concept of GISualization is outlined and explained through a broad range of examples of layer visualizations.

4. Results

4.1 A multi-layer GISualization framework

The GISualization framework is structured through five different layers of data, representing different methods for data collection as well as different grades of complexity, richness and interpretation (Figure 2): (1) basic statistics; (2) advanced statistics; (3) exogenous quali-

Table 1. The overarching analytical framework for compact city qualities developed by the research team. Compact city qualities are divided into states and the primary and secondary impacts of these states. For a fine-grained analysis these categories are further subdivided into five attributes.

Categories of Compact City qualities		Compact City attributes				
		Intensity	Diversity	Proximity	Connectivity	Concentration
State	People					
	Built structures					
	Nature					
Primary impacts	Socio-culture					
	Environment					
	Economy					
Secondary impacts	Health					
	Quality of Life					
	Justice					
	Adaptability					

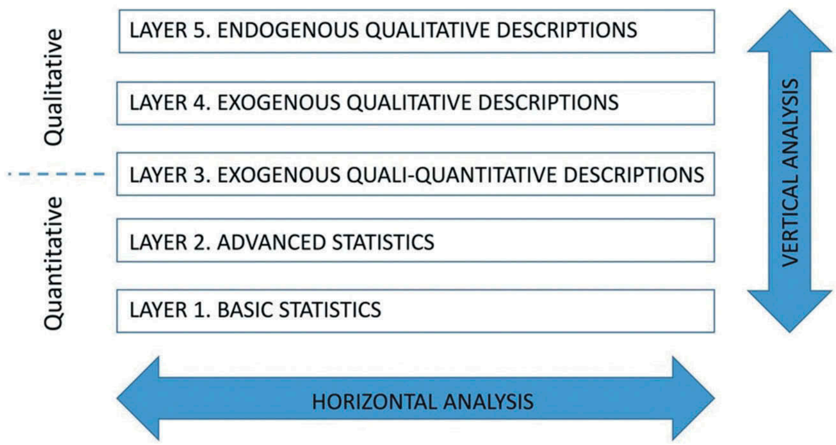


Figure 2. The five layers of the GISualization framework.

quantitative descriptions; (4) exogenous qualitative descriptions; (5) endogenous qualitative descriptions. Thus, the data displayed through such layers stem from both quantitative (1,2,3) and qualitative (3,4,5) sources. The statistics were divided into basic statistics and advanced statistics to highlight different levels of complexity. Layer 3, which is devoted to literature, includes the analysis of both quantitative and qualitative data. The discriminant between the qualitative layers is as follows: the exogenous layers represent the knowledge and perspectives of stakeholders and external researchers while the endogenous layer represents the more subjective and interpretative perspective of researchers being part of the research project at hand.

When it comes to the analytical process, it is divided in the same way (Figure 2). Different types of data are integrated horizontally (i.e. analyzed within the same layer, Section 4.2) and vertically (i.e. analyzed across multiple layers, Section 4.3). The vertical integration process is carried out first through analysis carried out by individual researchers, and then sharing/combining individual analyses with the research team through group learning. The analyses comprise both qualitative and quantitative methods, as well as both spatial and non-spatial relations (drawing on Brown et al., 2017), with an emphasis on the integration of GIS visualization with non-GIS visualization (Section 4.3).

4.2 *Data collection and horizontal GISualization analysis*

Quantitative data for the statistics layers (layers 1 and 2 in Figure 2) are mainly gathered from local and regional statistics together with municipal GIS data. Typical data formats include Office Excel files, tab-separated tables, shapefiles, 3D data and sometimes pdf files. Methods for horizontal data analysis in the basic statistics layer include, for example compilation of numbers and quantities, ratios, mean values, correlations and hot spots. For the advanced statistics layer, the same type of data sets can be used, but here for more complex horizontal analysis, such as cluster analysis (grouping of a set of objects with similar properties), Moran-index (measure of spatial autocorrelation), entropy (measure of diversity), space syntax (analysis of spatial configurations) and buffer zones (areas around input features to a specified distance). As explained in section 3, the exact type of data and methods to be used can be determined ad hoc for each specific research objective.

Qualitative data for the exogenous qualitative description layers (layers 3 and 4) are usually gathered from the literature (scientific and popular science literature as well as from other types of documents, such as policies, case descriptions), or from interviews (e.g. Brinkmann & Kvale, 2015) or focus groups (Kitzinger, 1994) with different stakeholders, including citizens. More advanced types of stakeholder interaction include, for example participatory workshops and co-design activities. Methods for horizontal data analysis include, for example content analysis (systematic reading, coding and categorizing of texts, images or voices to determine trends and patterns and correlations between the patterns, Schreier, 2012; Vaismoradi & Bondas, 2013); thematic analysis, "a method for identifying, analysing and reporting patterns (themes) within data" (Braun & Clarke, 2006, p. 79, for a comparison of content and thematic analysis see also; Vaismoradi & Bondas, 2013); and cross-comparisons of interviews. Participatory workshops (including spatial mapping of place perceptions) and co-design activities can be used for both data collection and analysis. For the endogenous qualitative description layer (layer 5), data are collected by researchers through different kind of mappings (with predefined or emergent categories), observations and by taking photographs or recording video. Examples of methods for horizontal data analysis are site analysis (LaGro, 2013), socio-spatial and functional interpretations, narratives, geo-ethnography or thematic analysis. Figure 3 exemplifies methods for data gathering and analysis as well as tools for data management and analysis for the five analytical layers of the GISualization framework.

4.3 Collaborative GISualization for vertical knowledge integration and synthesis beyond triangulation

The GISualization framework is conceived to facilitate cross-data analysis both horizontally and vertically for an improved understanding of complexity in urban studies. It combines place-based or geo-localized perspectives with a people-based approach, for example incorporating data from human beings on how they use space (Miller, 2007). Most of the horizontal analysis can be carried out by individuals (in our case researchers), although group learning provides additional layers of understanding, not least contributing to refined analytical questions and procedures. Parts of the vertical analysis can also be executed individually through reflective thinking (Johnston, 2014, e.g. identifying vertical relations or hotspots). However, a comprehensive vertical integration and synthesis of the different layers of quantitative and qualitative data is more demanding due to methodological challenges, for example linked to lack of data, contradictory findings, or incommensurable scales. Such challenges are best faced through the converging contributions of a multi-disciplinary group of researchers in a group learning setting (or with a wider set of stakeholders for a transdisciplinary dimension). For instance, the combination of different kinds of research expertise in a research team may help tackling questions of commensurability when dealing with diverse information layers (Johnson et al., 2007). Within such a process, team members "seek opportunities to develop new skills and knowledge" (London, Polzer, & Omoregie, 2005, p. 114). The GISualization framework functioned as a common platform for group learning among involved researchers, on which different sources of data were manifested, represented, visualized and integrated in support of advanced analysis. Although different types of analytical and visualization technologies were used, human interpretation and synthesis played a remarkable role in this process. With the purpose of extracting the added value of co-produced knowledge beyond triangulation, the outcome of the GISualization process was obtained through goal-oriented synthesis. As the participants of this learning process extracted information from each layer to improve their understanding of all layers, they produced new knowledge by entering an iterative process (Figure 4). This dialogue between the analytical work on different layers took the form of "an *interactive* approach (..) used where iteratively data collection and analysis drives changes in the data collection procedures" (Fetters, Curry, & Creswell, 2013, p. 2137).

At this point, group learning was essential for sharing and comparing different types of data, analyses and interpretations, subsequently leading to added and unexpected knowledge. Such a group learning process leads to the "acquisition and application of new knowledge to result in concepts", for example "learning the meaning of a new idea (or) making connections between two previously unrelated ideas" (MacLellan, 2005, p. 135). Here, a key feature is "the ability to extract what is central, essential, or generic from a context and create a mental

	LAYERS	DATA COLLECTION/SOURCES	DATA ANALYSIS	TOOLS
QUALITATIVE	ENDOGENOUS QUALITATIVE DESCRIPTIONS	Mapping, observations, photos, videos	Geo-ethnography, Narratives, Site analysis, Socio-spatial and functional interpretation	Maptionnaire, PPGIS, GISPro, Aerial photographs, text manager
	EXOGENOUS QUALITATIVE DESCRIPTIONS	Interviews, workshops...	Content analysis, Cross-compared interviews, Thematic analysis...	Mindjet, Nvivo, Atlas TI, Tagcrowd Web app, Excel, text manager...
	EXOGENOUS QUALI-QUANTITATIVE DESCRIPTIONS	Literature	Thematic/content analysis, frequencies, descriptive stats and radar graphs	Nvivo, Atlas TI, Tagcrowd Web app, Excel...
QUANTITATIVE	ADVANCED STATISTICS	Local, municipal, regional statistics...	Entropy index, Moran I, Hot spots, Cluster analysis, ...	Excel, GIS software, SPSS, Geo-segregation analyzer...
	BASIC STATISTICS	Local, municipal, regional statistics...	Basic demographics, density measures, means and ratios...	Excel, GIS software, SPSS

Figure 3. Data collection, data analysis methods and tools for data management for the five analytical layers of the GISualization framework.

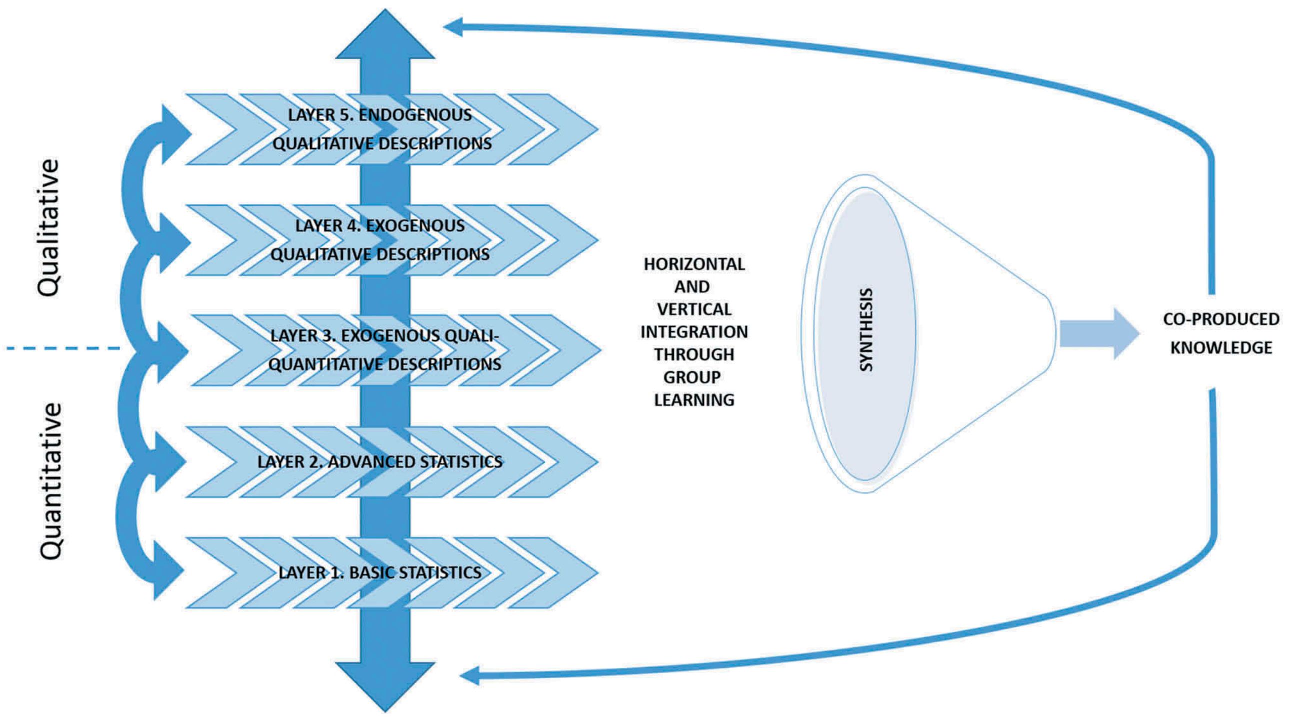


Figure 4. Iterative process of GISualization group learning for data integration, synthesis and added knowledge beyond triangulation.

representation of these attributes" (McMillan, 2009, p. 54). On a similar note, Braun and Clarke (2006) consider the identification of key topics/content as a milestone of qualitative research. Drawing both on McMillan (2009) and Braun and Clarke (2006) we adopt the term *core knowledge* to signify knowledge which stems from the selection of the most relevant/important issues that contribute to shaping urban qualities. Such core knowledge in the GISualization approach stems mainly from qualitative data derived from the literature and from interviews, focus groups, stakeholder workshops and similar activities (Section 5.2). This focus on qualitative data aims at avoiding any a priori categorization of information, since "if we use predetermined categories we may fail to identify important conceptions and ways of thinking" (Sharma Manjula, Stewart, & Prosser, 2004, p. 42). Nevertheless, in GISualization, the development of core knowledge is supported by "contextual information" (Davenport and Prusak (1998, p. 5) which allows for an assessment of the contribution of such core knowledge grounded in local situations and experiences. This is based on the idea that knowledge derives from "a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information" (Davenport & Prusak, 1998, p. 5). In Figure 2, layers 3 and 4 would typically represent core knowledge, while layers 1, 2 and 5 would provide contextual information. Even so, depending on the topic explored in the vertical integration process, what is defined/identified as core knowledge and as contextual information may shift, where layers expressing core knowledge in one situation can become a source of contextual information in another, and vice versa.

5. Examples of application of the GISualization concept

GISualization is a context adaptive approach which means that there is more than one solution for the selection of methods for data collection. In the following sections, examples of GISualization are provided based on data from two different cities. When references to particular cities are mentioned (e.g. in captions), they represent generic examples of application of the method for the purpose of this paper, that is not case study findings. The purpose of such representation is thus methodological rather than empirical. Representations include both horizontal data integration (i.e. across each of the five layers) and vertical data integration (i.e. analysis, synthesis and knowledge generation beyond triangulation). However, as this paper focuses on method development and not on empirical material from the specific case areas, the cases as such are not important. Instead, the figures are purely displayed to illustrate how the different layers can be applied.

5.1 Horizontal data integration

5.1.1 Layer 1—basic statistics

Different types of quantitative statistical data were visualized through ArcGIS 10.5, for example for a spatial representation of the daytime and nighttime population density, where the classification and visualization of the standard deviation showed the differences between different parts of a city (Figure 5). In this particular case, the comparison between the two types of densities improved the understanding of 24 h vitality/activity in different parts of a compact city. Apart from the obvious observation that high nighttime population density tends to lead to low daytime population, such basic horizontal integration serves to identify areas for further detailed studies, e.g. based on occurrence of simultaneous high or medium nighttime/daytime population density.

Another example of horizontal integration of basic statistical data was obtained through a reflective thinking process (Johnston, 2014) linking compact city qualities as states with their impacts. In this analysis the purpose was not to define a threshold or optimum density of inhabitants. Instead, a bidirectional reflection on a state (e.g. demographic density) and its impact indicator (e.g. density of associations) helped the researchers to understand, for instance, what level of demographic density exists when a high presence of civil associations is detected and vice versa (Figure 6). This was thus not a simple convergence or triangulation of data but a bidirectional confrontation looking at both states and impacts to see how the variation of one indicator affected the other. Such reflective reasoning implied that compact city qualities do not need to be equally represented in all localizations but can vary according to local contexts.

5.1.2 Layer 2—advanced statistics

Besides visualizing and reflecting on basic statistical data, statistics were also combined in more complex ways in order to study relationships of different compact city qualities. For example, the *GeoSegregation Analyzer* (Apparicio, Martori, Pearson, Fournier, & Apparicio, 2014) was applied to examine social aspects, such as social diversity and the relationship between densities of host (majority) populations and ethnic minorities. This tool was also used for calculating an entropy index, showing the degree of diversity across population nationalities (Figure 7). The versatility of this tool facilitates exploration of different topics, such as diversity in service provision or land uses.

5.1.3 Layer 3—exogenous qualitative/quantitative descriptions: literature

One set of data was collected by a review of journal articles from year 2012 to 2015, using the search term "compact city" (Kain et al., 2016), where the literature itself is based on a mix of qualitative and quantitative research data. A quantitative assessment was carried out, sifting out and counting what terms were used to label purported (or debated) qualities of compact cities, grouping these terms into main categories (as in Table 1) and visualizing the incidence of these categories through an *Office Excel* radar chart (Figure 15(a)). The reviewed articles were also sorted according to their geo-economic context (i.e. Global North, BRICS, Global South), showing differences in the priorities of research oriented towards the Global North and South, respectively.

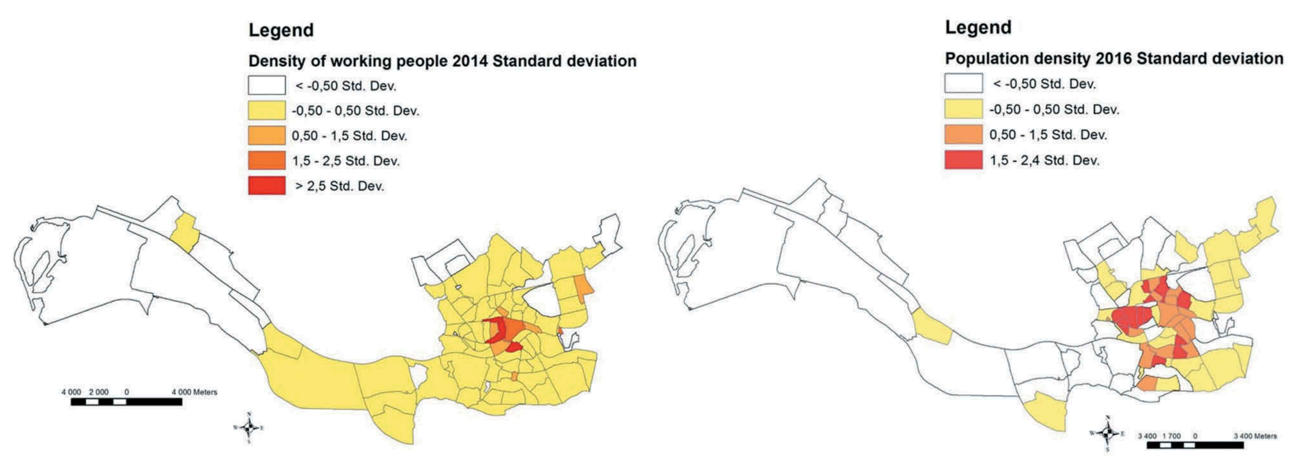


Figure 5. Example of horizontal data integration for the basic statistics layer. Visualization of the daytime and nighttime population density (standard deviation) in Rotterdam GIS maps. Data source: Rotterdam municipality and statistics Netherlands (CBS).
Rotterdam Municipality and Statistics Netherlands (CBS)

Categories of Compact City qualities		Compact City attributes				
		Intensity	Diversity	Proximity	Connectivity	Concentration
State	People	Inhabitants/Ha or km^2 (demographic density)				
	Built structures					
	Nature					
Primary impacts	Socio-culture	Density of associations, restaurants, bars, etc.				
	Environment					
	Economy					
Secondary impacts	Health					
	Quality of Life					
	Justice					
	Adaptability					

Figure 6. Example of bidirectional reflective reasoning based on GISualization of population density and density of social venues, and on the horizontal data integration of these basic statistics. This analysis expands on the framework presented in Table 1.

5.1.4 Layer 4—exogenous qualitative descriptions: interviews

Qualitative data were also gathered from interviews carried out by the research team with different stakeholders (planners, representatives from associations and NGOs, developers, property managers, citizens, researchers, etc.) and from workshops with inhabitants. The mind mapping tool *MindJet MindManager 2016* was used for visualization of themes from the interviews, that is to summarize and visualize what the interviewees talked about but also *how* they talked (Figure 8). The coding was based on the previously conducted literature review (Kain et al., 2016) and was carried out in *Office Word* to make the material easily accessible to the whole research group. In addition to visualizing main themes, the mind mapping tool also facilitates organizing the qualitative data in different levels of detail and specificity. While the data source in this layer is always qualitative—which is where the layer's name originates from—the a posteriori analysis may lead both to quantitative GIS mapping (e.g. hotspots, positioning of statements or dot density maps as illustrated in Figures 10, 11 and 14) or qualitative representations (e.g. qualitative content analysis of themes).

Additional qualitative data were gathered through workshops and interviews about perceptions of different neighbourhoods, spatially linked to maps. In a workshop carried out in one of the case areas, residents were asked to place dots on a map (a print-out of an aerial photograph, size A0) to mark places they liked (green dot) and disliked (red dot, Figure 9). The result is a quantitative visualization of clusters of dots, indicating hotspots of likes/dislikes. The qualitative comments regarding why these spots were chosen were also recorded, again linking qualitative statements to urban space.

In one of the cities, students interviewed inhabitants in a survey format and the results were compiled, analysed and presented using *Maptionnaire* (www.maptionnaire.com), a software as a service (SaaS) for creating map-based questionnaires and civic participation platforms (Figure 10). In this example, there was an interpretation component when the students helped the respondents linking the survey responses to maps. When using Maptionnaire, the analysis directly resulted in place-based visualizations of clusters of dots and heat-maps illustrating hot spots due the digital data integration, but where each dot contains additional qualitative information.

5.1.5 Layer 5—endogenous qualitative descriptions: observations

For qualitative data based on observations on site, place-markers were integrated with photographs and qualitative observations, documented and categorized by the researchers (i.e. type of space, atmosphere, activities, infrastructure, design, ground floor activities, upper floor activities, date). For the mapping, the geospatial app *GIS Pro* was applied using a mobile device (*iPad*). The files were imported to *ArcGIS* for further analysis. Figure 11 shows an example of a typical visualization of the data, integrating maps with points of observations, with related photographs and with the researchers' observations and interpretations of places in one of the case districts.

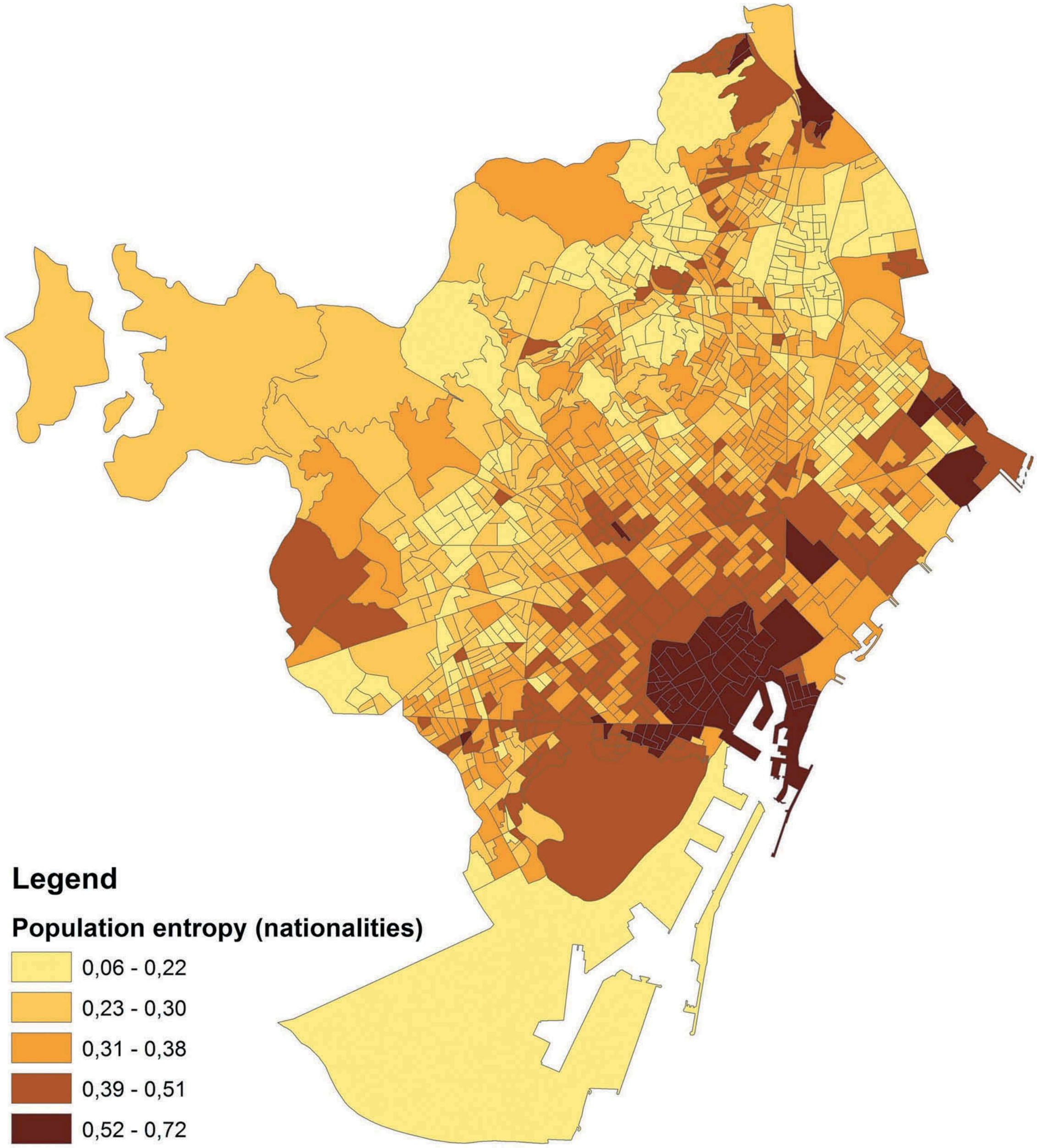


Figure 7. Example from the advanced statistics layer: Population entropy of nationalities in Barcelona at census tracts level, ranging from minimum (0 = light colour) to maximum (1 = dark colour) diversity of the population. Data source: Barcelona municipality and Catalonia's Institute of Statistics.

Barcelona municipality and Catalonia's Institute of Statistics

Subsequently, a more comprehensive interpretation of the qualitative data was carried out by the researchers, sometimes supported by other types of data (e.g. *Google Maps* and *Google Street View*) filling in a matrix based on the compact city framework presented in Table 1. The result was an iconographic analysis of the case districts. First, the descriptive qualitative data was colour coded for each place-based observation point (using a 5-categories Likert scale, from dark red = very low to dark green = very high). This colour coding was then aggregated into a single number for each cell of the table (from 1 = very low to 5 = very high) through own interpretations and weighting of the various urban qualities observed, and then further aggregated into average values for ten main categories of compact cities qualities (Figure 12). This iconographic analysis is a place-less visualization of place-based data and signifies an increasing level of abstraction.

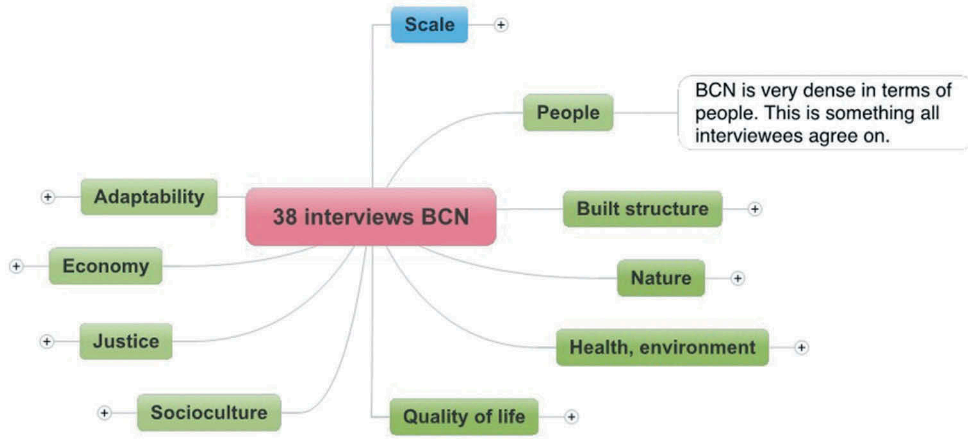


Figure 8. Example of non-spatial visualization of clustered interview themes (compact city qualities, see Table 1) using MindJet MindManager 2016.

Figure 9. Example of spatial visualization of perception of places through a residents' workshop in a Barcelona district, where residents placed dots on a map to mark places they liked and disliked, and also commented on why they had these perceptions.

5.2 Vertical integration

Although horizontal integration of data at the different layers leads to important insights, it is the vertical integration of data that is the main strength of the GISualization methodology. The horizontally integrated data were thus also integrated vertically to gain the desired synthesis and added knowledge beyond triangulation. Half-day and one-day workshops on certain topics were carried out as group learning sessions with all members of the research team. The vertical integration did not aim to include all data from all layers but to engage in deepened analysis of thought-provoking or puzzling results identified through the horizontal integration. Data from different layers, assessed by the researchers as relevant, were combined to explore a specific topic through dedicated *integration sessions*. The development of added knowledge through such sessions relied on the expertise—or *brain work*—of the researchers, typically based on the various horizontal layers of data. Such a posteriori reflection on research results is mainly a top-down approach (Gray & Densten, 1998). Still, the input of data for developing this added knowledge included a strong bottom-up perspective, e.g. through qualitative data from interviews and workshops. Five examples of such vertical integration are described in

Figure 10. Example of spatial visualization of perceptions of places as a heatmap, using the software Maptionnaire. Surveys collected from citizens in the street in a Rotterdam district were translated into markers of places they liked and disliked and were digitally analysed, where each such marker contains additional qualitative data.

Figure 11. Observations mapped with GIS Pro and subsequently imported into ArcGIS. Example shown here: Barcelona's district of Les Corts. Source of the base layer of the map: Barcelona municipality.

Sections 5.2.1 to 5.2.5 (Figure 13): a) integration of basic and advanced statistics; b) interviews and literature; c) geo-mapped statistics and interviews; d) site observations and statistics; and e) cross-cutting issues.

The vertical integration sessions started with a discussion around what *core knowledge* (Section 4.3) was found in the qualitative material during the horizontal analysis, leading to a selection of the most relevant

	Intensity	Diversity	Proximity	Connectivity		Total
People	4	4	4	5	P	4,25
Built structures	4	5	5	4	B	4,50
Nature	3	1	2	1	N	1,75
Socioculture	3	4	2	2	S	2,75
Environment	2	1	2	3	E	2,00
Economy	4	4	4	5	€	4,25
Health	1	1	4	4	H	2,50
Quality of Life	4	3	4	4	Q	3,75
Justice	5	4	3	5	J	4,25
Adaptability	2	4	3	2	A	2,75

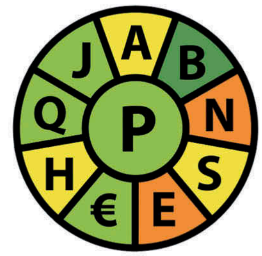


Figure 12. Iconographic analysis of site observations in relation to the compact city framework (Table 1). Example of place-less visualization of place-based data for one observation point. Qualitative descriptive data for each cell of the framework are aggregated into a single number (table to the left), subsequently further aggregated into average values for ten main categories of compact cities qualities (table in the middle and circle chart to the right).

topics for deeper vertical inquiry. As an example, issues related to the compact city quality "ethnic diversity" emerged as a vital topic in interviews and the literature, thus constituting core knowledge. Empirical material from all layers (both qualitative and quantitative data) relevant for the topic in focus was then studied and reflected upon to attain vertical integration, e.g. print-outs of maps; digital interactive maps; ppt presentations of results from layer analysis (both data and horizontal integration); and oral input from the researchers. Quantitative proxy indicators (e.g. entropy index showing ethnic diversity) were hence not selected a priori, but only as a consequence of that the issue of ethnic diversity emerged as core knowledge in the qualitative sources. As a matter of fact, starting with quantitative indicators to identify compact city qualities would have been problematic, as the selection of relevant topics (core knowledge) could have been biased, for example by presumptions by the researchers or availability of data at the local scale. Nevertheless, as already noted in Section 4.3, quantitative data within GISualization can still provide core knowledge. This was confirmed during vertical integration where correlations between different statistical data contributed to filtering and selecting the most relevant data to focus on. For example, the correlation between the diversity of nationalities and the number of restaurants in the quantitative statistics layer said something important about this topic and was therefore judged as important core knowledge.

Table 2 summarizes how the five instances of vertical integration of data between layers in Figure 13, were seen to link to different categories of compact city qualities, what analytical methods were applied, rationales for the choice of each method, and findings deriving from the vertical analysis. All methods used in the Compact City research project are not listed since the inclusion of methods and rationales in the table exclusively aims at providing examples of the work process.

5.2.1 Basic and advanced statistics

Quantitative data (e.g. population, nationalities, and civil associations) were combined in different ways (Figure 14) to further analyze the complex issue at hand, gathering gradually increasing knowledge on issues related to different compact city qualities and attributes (Table 2). For example, the standard deviation allowed displaying how dispersed the demographic distribution was (Figure 14 (a)). The density of population was classified through natural breaks, minimizing variance within classes and the top categories were selected to identify very high population density. Such high levels of population were then compared with an entropy or diversity index referred to nationalities (Figure 14(b), see also Section 4.2). *IBM SPSS* supported the exploration of statistical correlation between the variables visualized on these GIS maps (Figure 14(c)). Statistical correlations were also used to filter other variables and find the most relevant indicators to describe and analyze compact city qualities. The *Accessibility Index ArcGIS tool* ***[1]***, based on a population potential algorithm (Geertman & Ritsema Van, 1995), was used to calculate if facilities were located close to a census tract with high or low population, which served to evaluate people's potential access to these facilities (Figure 14 (d)). The use of the Euclidean distance is not as sophisticated as other types of space-syntax or network analyses but served as good approximation for this type and scale of analysis.

This first instance of vertical integration revealed that, although social diversity is typically seen as a positive impact of high population density (e.g. Boyko & Cooper, 2011), the empirical evidence did not support this in a strong manner, since the correlation between population density and diversity of nationalities existed but it was not particularly high. Furthermore, while compact cities are expected to lead to social activity and interaction (Rani, 2015),

Table 2. Connection between layers, categories of compact city qualities, examples of applied methods, rationale for analysis and examples of findings.

Layer(s) (see Figure 13)	Compact cities qualities	(Examples of) Methods	Rationale	Findings
1 + 2 (Section 5.2.1)	People Socio-culture	Population density +entropy Population potential (accessibility index)	Connection between density and diversity as compact city attributes Proximity of services/facilities as expression of intensity and proximity as compact city attributes	Potentially questioning the claim that high population density leads to social diversity Linking occurrence of civil associations to historical conditions rather than to population density and accessibility
3 + 4 (Section 5.2.2)	All	Thematic content analysis + frequencies of compact city qualities	Coverage of compact city qualities	Clear discrepancy between the perspectives of academia and urban stakeholders
1 + 4 (Section 5.2.3)	People Socio-culture Economy	Content analysis + percentage variation of economic activity	Understanding underlying reasons for economic activity and resistance	Clear differences in stakeholder perspectives in areas with similar levels of economic activity but different historic trajectories
1 + 5 (Section 5.2.4)	All	Population density + iconographic analysis of site observations	Relating observed compact city qualities to population density data	Clear local variation in perceived compact city qualities compared to available statistical data
1 + 2 + 3 + 4 + 5 (Section 5.2.5)	All	Mindmapping + group learning	Finding qualitative correlations within and between case cities	Identifying similar themes and challenges in the two case cities, but significant differences in how these themes and challenges were appreciated and addressed

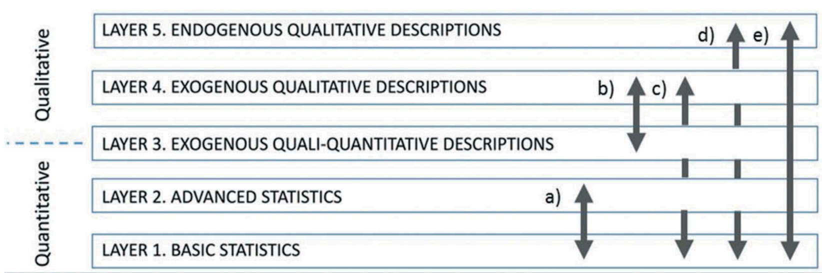


Figure 13. Five examples of vertical integrations: a) integration of basic and advanced statistics; b) interviews and literature; c) geo-mapped statistics and interviews; d) site observations and statistics; and e) cross-cuts.

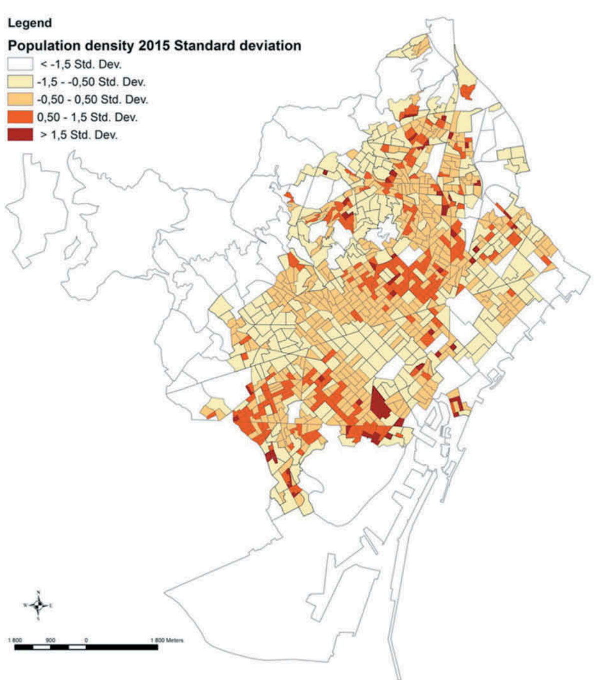
the example of the accessibility index displayed in Figure 14(d) revealed that the occurrence of civil associations is only partially related to population density. Instead, a strong factor of influence was related to historical urban development processes. For a deeper understanding of the accessibility of associations in relation to different population groups (e.g. children, elderly, ethnicity), both associations and population need to be divided into subgroups and analyzed separately.

5.2.2 Interviews and literature

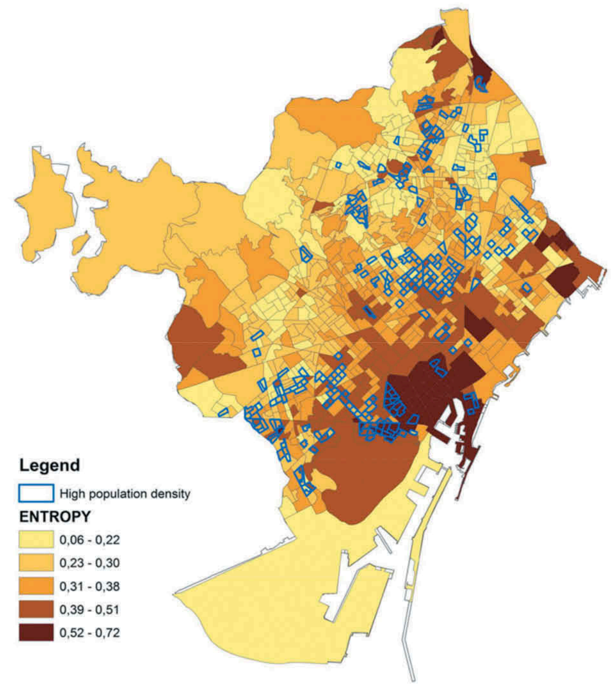
The occurrences of different themes in the content analysis of the literature (Section 5.1.3) and interviews (Section 5.1.4) were visualized as *Office Excel* radar charts for a quantitative representation (Figure 15(a,b)). Vertical integration was achieved by merging these two radar charts, indicating a clear discrepancy between the priorities of the academic literature and what stakeholders in the case cities found to be important aspects of compact city development (Figure 15(c)). While the academic literature tended to focus on the physical built environment (i.e. building stock, land use, transport), urban stakeholders in the case cities had a strong emphasis on the "softer" aspects of compact cities (i.e. health, quality of life, socioculture, economy and adaptability). This overlay of data from different sources immediately led to new analytical perspectives.

5.2.3 Interviews and map-based statistics

Interviews were also georeferenced and combined with GIS maps displaying statistics. For example, the building floor area devoted to economic activity was combined with extracts/quotations from interviews on the same topic (Figure 16). Interviews either confirmed what was expressed by statistics (e.g. the importance of economic activity in a certain area) or added extra knowledge and nuances whose level of enrichment went beyond



a)



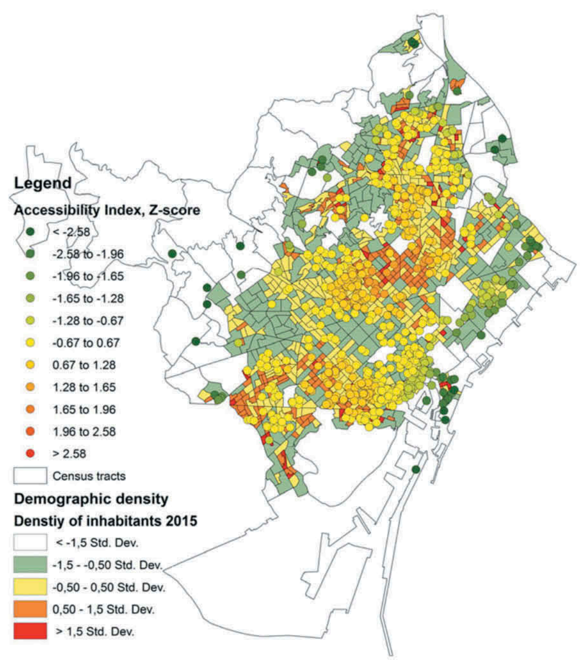
b)

Correlations

		total	entropy
total	Pearson Correlation	1	,371**
	Sig. (2-tailed)		,000
	N	1068	1068
entropy	Pearson Correlation	,371**	1
	Sig. (2-tailed)	,000	
	N	1068	1068

**Correlation is significant at the 0.01 level (2-tailed).

c)



d)

Figure 14. Examples of vertical data integration and analysis, including GIS visualization and statistical correlation: a) standard deviation of demographic density 2015; b) high population density and diversity (entropy); c) correlation between high population density and diversity (entropy); and d) population potential of civil associations (accessibility index tool). Example taken for these maps: Barcelona. Sources of data and of base GIS layers: Barcelona municipality and Catalonia's Institute of Statistics.

simple triangulation (e.g. economic activity might be linked to speculative real-estate, offices or incubators). It became clear that perspectives among interviewees differed significantly between two areas with similar high shares of the building area devoted to economic activities. In an area largely consisting of browfield redevelopment, arguments were linked to city branding and positioning in global markets while stakeholders in

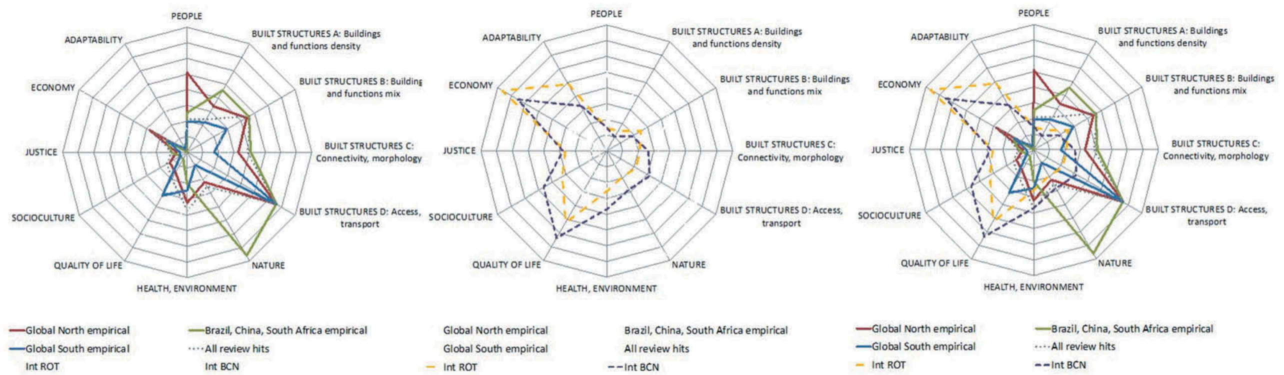


Figure 15. Non-spatial visualization of results from the content analysis of compact cities qualities mentioned in the literature on compact cities and in the interviews (this example is referred to Barcelona and Rotterdam): a) quantitative content analysis of literature; b) quantitative content analysis of interviews; and c) vertical integration of literature and interviews showing discrepancies in perspectives between the communities of researchers and urban stakeholders.

a centrally located consolidated but poor neighbourhood displayed more critical perspectives vis-à-vis the speculative economy.

5.2.4 *Site observations and map-based statistics*

Quantitative statistics were complemented with information deriving from qualitative site observation to provide a clearer idea of the urban qualities present in a specific location. The place-less iconographic aggregations and visualizations for each observation point described in Section 5.1.5 (Figure 12) were fed back into the analysis on top of basic statistics maps, showing for example population density, thus integrating place-based and people-based data (Figure 17). It was found that combining place-based statistics and site observations provided a more diversified information regarding physical qualities which did not emerge merely through the statistics. For example, it became clear that the perceived density of the building stock in a neighbourhood varied significantly compared to the uniform density visible in maps based on statistical data. The same was apparent for, for example sociocultural, economic and quality of life aspects.

5.2.5 *Cross-cuts*

A final example of vertical analysis is the identification and development of qualitative correlations, termed *cross-cuts* by the research team. These cross-cuts were developed through full-day workshops with all involved researchers, where all data and horizontal integration for the two cities were presented, discussed and processed through group learning. For example, data from the interviews were presented in the form of visualizations of how the interviewees talked about compact city qualities. This knowledge was then compared with, e.g. statistical data about tourism or place-based data about diversity. These discussions did not only triangulate information from all layers, but also developed new knowledge beyond triangulation stemming from the data, from the researchers' accumulated knowledge and experiences, and from the joint learning process. The new knowledge, in turn, led to a second round of analysis of the interviews, identifying issues that cut across one or more of the categories of compact city qualities found in Table 1 (Figure 18). Additionally, the analysis of cross-cuts facilitated a comparison between the cities, identifying a number of themes that were shared by the two cities but interpreted and acted upon in very different ways, including how to brand the city to stimulate economic development; how to work with temporary and transitory urban space; how to improve accessibility and mobility; how to green the city; how to build urban resilience; and how to strengthen citizen engagement and urban equity. As with the data described in Section 5.1.4, a posteriori analysis may link these findings back to specific urban geographies through combined quantitative/qualitative GIS mapping.

6. Discussion and conclusion

The GISualization approach is closely related to systems thinking (Senge, 1997) and complexity theories (Batty & Marshall, 2012) in the way it structures and interrelates different types of complex informational layers through a systems-based "holistic process of inquiry" (Gharajedaghi, 2011, p. 136) for the understanding and management of urban complexity. The structure of the framework recalls, in part, Steinitz' Geodesign framework (Steinitz, 2012), especially in terms of its collaborative use of information; a multi-layered structure and iterative process. Still, the GISualization framework is focused

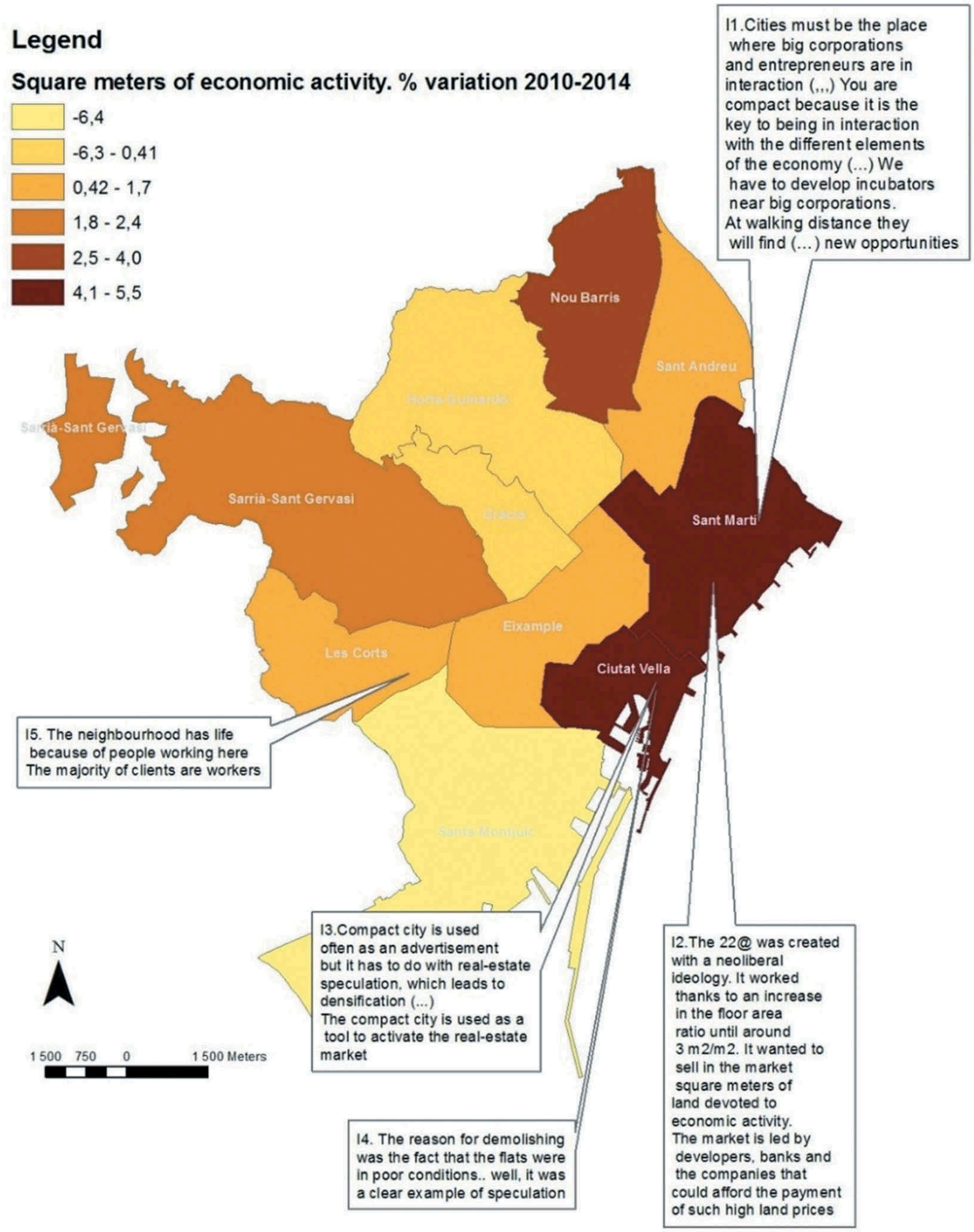


Figure 16. Example of integrated geo-visualization of basic statistics and interviews. Square meters of building floor area devoted to economic activity in Barcelona combined with extracts from interviews. Data source: Barcelona municipality and Catalonia's Institute of Statistics.

Barcelona municipality and Catalonia's Institute of Statistics

more on analysis and finding a common platform among researchers (and potentially among a wider set of urban stakeholders) for understanding complex and still unclear urban phenomena (such as compact city qualities) rather than on design, decision-making and production of change. Through its dedicated quali-quantitative approach it can thus be seen as complementary or supplementary to the first three models of Steinitz' Geodesign framework (i.e. description, functioning and evaluation of the urban landscape).

Furthermore, knowledge in GISualization is produced through an iterative analytical process in a research environment that avoids the use of any predefined theoretical lens. By doing so, it resembles Knigge and Cope (2006) use of grounded theory connected to GIS. GISualization embodies a collaborative communication

Figure 17. Example of integration of map-based statistics on population density and qualitative site observations in a Rotterdam case district. Place-less iconographic visualizations (small circle charts, see Figure 12) and an average for all observations in the case area (large circle chart) now re-represented as place-based data. Background picture: courtesy of MB-Research and ESRI.

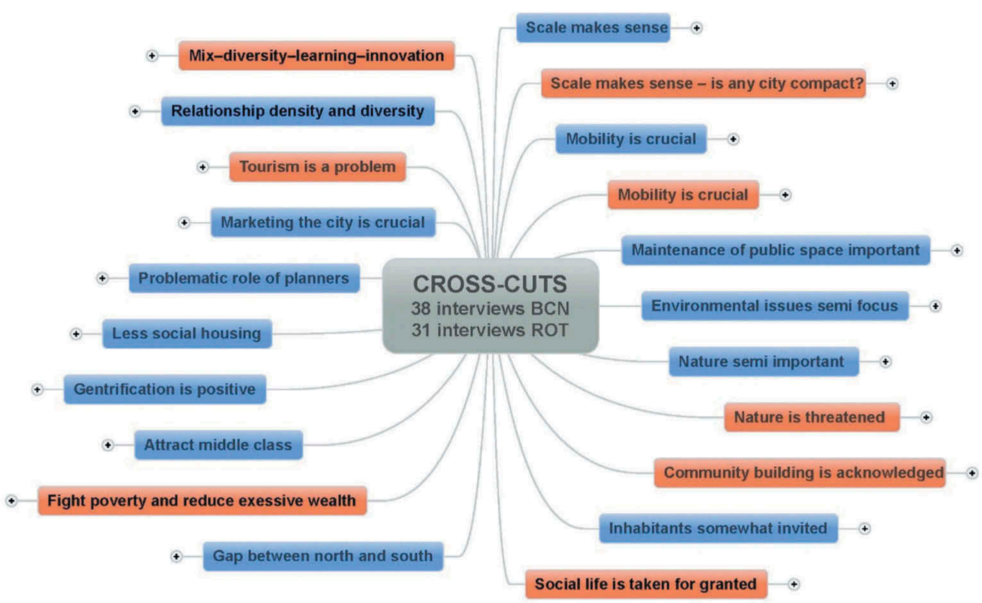


Figure 18. Cross-cuts stemming from two different examples of cities (blue and orange boxes representing Rotterdam and Barcelona, respectively) showing similarities and differences in main themes of compact city development. In the software Mindjet, each box is clickable and contains further qualitative information supporting joint learning in a further detailed analysis.

platform that provides a language to navigate between, and take advantage of, heterogeneous data, information and methods. The dialogue between qualitative and quantitative data displays significant commonalities with Morgan's (2007) abductive approach based on pragmatism. The main commonality between such an approach and GISualization can be found in "intersubjectivity" as "relationship to research process", which Morgan associates with both abductivity and pragmatism (Morgan, 2007, p. 71). Nevertheless, the

GISualization approach partially diverges from Morgan's abductivity, which adopts a sequential combination of methods, as it pursues a concurrent collection and elaboration of mixed data. Although the GISualization framework includes both quantitative and qualitative layers of information, it adopts an open-ended and pragmatic methodological pluralism, allowing for different levels of combination of methods according to the specific needs of research. No a priori quali-quantitative methodological balance is taken for granted as a best solution for all types of studies (Johnson & Christensen, 2014; Johnson et al., 2007). Still, as said in Section 3, GISualization may be described as being methodologically mixed, but "qualitative dominant" (Johnson et al., 2007, p. 124). As GISualization is context-sensitive, the most adequate application is to use it in an adaptive and flexible way. Non-quantifiable elements and context-dependent factors (e.g. socio-cultural or political aspects) emerge from a mixed-method knowledge development and analytical process and such elements need to "be inferred indirectly from the observable facts" (Cronshaw & McCulloch, 2008, p. 101). For this reason, the actual mix of quantitative and qualitative information may vary from context to context, since the analysis of similar quantitative indicators may produce different results in different locations through their vertical integration with qualitative data.

Based on the experiences of the research team, the GISualization approach has proven to be a methodological framework that makes it possible to visualize and analyze complex data in a rich format. Compared to the many other methodological approaches experienced by the team in numerous previous research projects, the mixed-method approach anchored in group learning delivered a both wider and deeper understanding of the complexity inherent in urban development challenges. For moving the analysis beyond triangulation, GISualization emerged as especially valuable for its ability to combine GIS-based visualization with other types of data and their correspondent visualizations. Spatial visualization connected to maps (GIS visualization) still maintains a fundamental value, but non-spatial visualization—for example statistical correlation tables, non-spatial visualization of interview themes, iconographic matrices, etc.—can seamlessly be integrated depending on particular research needs. For the vertical integration of such a diverse and complex range of data sources, which aims to accomplish more than mere triangulation of data, the human side of the process is fundamental. It is evident that group learning becomes central to grasping complexity and incorporating multiple "viewpoints rather than a single God's eye view" (Goodchild, 2011, p. 129). Such an integrative approach does not diminish the importance of GIS, but increases its value as a provider of rich data and robust data management capabilities for further collaborative interpretation and synthesis. It is not by chance that the approach presented in this paper is defined as GISualization, maintaining that visualization of GIS data is a fundamental tool for human interpretation of complex research outcomes.

Nevertheless, working with mixed data sources also revealed problematic aspects which affect both data collection and analysis. First, identifying the most adequate geographical scale(s) may be challenging as it does not exclusively depend on the object of study. For example, the scale of analysis is also influenced by the availability of statistical data at an appropriate resolution while qualitative findings from interviews and observations are not constrained by such administrative issues or restraints in capacity. Second, triangulation of findings may produce different types of outcomes. Following Yeasmin and Rahman (2012, p. 160), results of triangulation may be *convergent, inconsistent* or *contradictory*, where inconsistency may hinder comparability of data but does not necessarily imply contradiction. Third, moving beyond triangulation is even more challenging. As explained in the literature review, methods for an integrated analysis beyond triangulation are still lacking and results have, so far, not been sufficiently comprehensive. As stated by Greene (2008, p.14), mixed-method research may have other purposes besides triangulation: *complementarity, development, initiation* and *expansion*. Triangulation may also lead to an enriched comprehension or *added knowledge* resulting from combining different layers of information.

Moreover, the GISualization framework has until now been developed in a quite narrow research context and the knowledge has been co-produced solely by researchers. Future development and application of the approach need to include broader stakeholder involvement and community participation extending into the domain of transdisciplinary knowledge production (Roux, Nel, Cundill, O'Farrell, & Fabricius, 2017; Thompson Klein, 2014). Linking GISualization to the political domain of urban transformation processes, including agenda-setting, problem formulation and decision-making (Friend & Hickling, 2005), would extend GISualization to engage also with the intervention mode of Steinitz (2012) Geodesign framework.

Furthermore, in the future, GISualization can play an important role, not only in knowledge co-production, but also in knowledge dissemination as it makes it possible to merge scientific (e.g. statistics) and non-expert (e.g. local residents') knowledge (Talen, 2000). Research has acknowledged the role of visualization for promoting dialogue in urban planning (Billger, Thuvander, & Stahre Wästber, 2016), participatory planning (Al-Kodmany, 2001; Kahila & Kyttä, 2009; Talen, 2000), design empowerment (Elwood, 2006) and improved education (Drennon, 2005; Li, 2010). Still, the full potential and perils of integrative visualization in support of urban transformation processes is not sufficiently explored (Billger et al., 2016). The use of visual representation in urban planning and design has a rhetorical value as a "persuasive system" which is still "under-explored" (Pojani & Stead, 2015, p. 586) where a major risk is that "maps can aggravate and exacerbate problems when they are misused" (Esnard, 2012, p. 311) by (covertly) imposing the mapmaker's perspective. Critical GIS studies (Schuurman, 2006) have revealed concerns about how power and entitlement influences technological, epistemological and methodological aspects of GIS. The unintentional or conscious decisions of mapmakers about what to represent on maps and how this is done may lead to a vision (or visualization) of reality which is not universal (Monmonier, 2018). Likewise, the presented information can be filtered to highlight specific aspects leading to misinterpretation or even manipulation (Billger et al., 2016). In this context, due to its focus on multiple and unbiased sources of data, analyzed through inclusive group learning and co-production of knowledge, GISualization based on wide and inclusive stakeholder participation is empowering and serves to balance asymmetries in power among urban stakeholders, including citizens.

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